Lab Sea in coupled simulations: sensitivity to resolution in CESM1 and comparison to observations

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Naïve discussion Slide (to be returned to)

• Do you need to explicitly resolve ocean eddies
  • To restratify water column in correct location
  • – possibly reduce sea ice formation?
• Do you need to better resolve boundary currents
  • To get correct transport of water properties
  • To reduce local T/S bias
• Do you need realistic location of deep convection in Lab Sea to ensure realistic AMOC?
• If yes to above, is it sufficient to use mesh-refinement?
  • Where would you refine?
  • AMOC is a basin-wide phenomenon
FIG. 1. Sketch of the circulation in the Labrador Sea. EGC and WGC are the East and West Greenland Currents, respectively. LC is the Labrador Current, IC is the Irminger Current, and NAC is the North Atlantic Current. Dashed lines correspond to the middepth cyclonic recirculations reported by Lavender et al. (2000). Also displayed on this sketch are the WOCE AR7W hydrographic line (thick black line) and the OWS Bravo (star). Isobaths 1000, 2000, and 3000 m and the location of the deep convection site (shaded ellipse) after Pickart et al. (2002) are shown.

From Chanut, Barnier, Large, ... et al 2008
Ocean circulation

Kieke and Yashayaev 2015 Prog. Oceanogr. Based on ARGO float data 2002-2012

Note cyclonic boundary currents

Return flow from lab Sea to Irminger Sea

Pickart et al 2008

Note Cyclonic gyres
Convective mixing in Labrador Sea

- Cyclonic circulation (previous slide) and doming of isopycnals preconditions for effective erosion of stratification by mixing
- Large air-sea heat loss and strong wind stress in winter
- Deep mixing occurs in preferred locations

Holte et al. 2017. ARGO MLD
Pickart et al. 2003
Hydrographic structure along WOCE line. From Yashayaev 2007.

Note the large differences between the different years. Labrador Sea Water very thick in 1994, not-so in 2005

Note the very fresh water at boundaries near surface

Also warm and salty water offshore and deeper
Role of ocean eddies

• Eddies play an important role in restratification process
  • limiting depth, spatial extent and duration of deepest mixed layers
  • (Pickart et al, Spall et al, Chanut et al, Moore et al)

• Several types of eddies identified:
  • Irminger Rings (Lilly 2003, ...)
    • generated by interaction of west Greenland current with topography at Cape Desolation
    • Travel into interior
  • Boundary current eddies
    • Baroclinic instability of the boundary currents
  • Convective eddies on rim of convective patch
  • Eddies may cause restratification through heat or freshwater
Irminger Rings: source of EKE and restratification

Fig. 24. \( V_{EKE} \) for the Labrador Sea during the seven-year period 1994–2000. The shading and contours are as given in the legend. TOPEX / Poseidon ground tracks are shown by dotted lines and the coastline is shown with a thick black line. \( V_{EKE} \) has been set to zero for depths shallower than 500 m due to concerns about altimeter performance in coastal regions. A region defined as the “Labrador Sea interior” is shown by the thick dashed line, and follows the 3000 m isobath except for where it cuts between two bathymetric ridges to form a closed loop. The three rectangular boxes define regions referred to as the northern, central, and southern regions, respectively. The location of the Bravo / K1 moorings is indicated by the circles, and those of other moorings by triangles. The AR7W WOCE hydrographic section is shown by the thick black line. Latitude and longitude are shown on the right-hand and top axes edges, with distance (in units of 100 km) based on a Cartesian expansion about a point (58.5° N, 52° W) near the center of the Labrador Sea interior shown on the left and bottom edges.

Fig. 16. Bottom topography showing the region of steep slope along the west coast of Greenland (bottom contours are 500–3500 m by 500-m increments) along with the surface eddy kinetic energy (after Fratantoni 2001).
Note: large air-sea heat fluxes in winter associated with cold air outbreaks (Alice talk) and ice edge
But large air-sea fluxes may not be directly dependent on the sea ice location (Moore et al 2014)
Suggestion that deep mixed layers form where air-sea heat flux is large AND eddy restratification is weak
CESM 1 simulations

- Suite of simulations with ~ CESM1.2
  - Similar to CESM-LE but with CAM5-SE
  - Small et al. 2014 (JAMES)
    - Shameless plug for some old simulations
- 100 year simulations under year 2000 conditions
- High-resolution (old “ASD”)
  - 0.1deg. Ocean-ice, 0.25deg atmosphere
- Mixed resolution
  - 1deg. Ocean-ice, 0.25deg atmosphere
- Standard resolution
  - 1deg. Ocean-ice, 1deg atmosphere
MIXED LAYER DEPTH (HMXL) IN JFM IN LAB SEA

ASD run: 0.25deg atm, 0.1deg ocn. 30 year average

Mixed-res equivalent: 0.25deg atm, 1deg ocn. 30 year average

Standard-res equivalent: 1deg atm, 1deg ocn. 30 year average

Caveat: this version of 0.25deg CAM5-SE had very smooth topography – improved more recently
Net Surface heat loss in Lab Sea in JFM. Negative values cool ocean

Refine Atm resolution

Refine Ocn-Ice resolution
SSH variability (expressed as standard deviation) in Lab Sea (Annual).

HIGH-RESOLUTION CESM

Satellite Altimetry
Deep mixed layers form away from strong eddies and strong boundary currents and not in regions of highest air-sea heat loss.
TEMPERATURE AND SALINITY BIASES

SST bias high-res

SSS bias high-res

Salinity (1000m) bias high-res

SST bias mixed-res

SSS bias mixed-res

Salinity (1000m) bias mixed-res
AMOC

ASD run: 0.25deg atm, 0.1deg ocn. 30 year average

Dark black line- high-res
Light line – standard res

Standard-res equivalent: 1deg atm, 1deg ocn. 30 year average
Discussion Slide

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Extra slides

V velocity in 1.) ASD run 2. Standard-res run.

Note much weaker flow in Lab Sea margins in standard res.
Patterns with barrier flow have positive correlation with frequency and seasonal deepening.